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Roughness of Thermally Modified Wood at Milling

MONIKA KVIETKOVÁ, MIROSLAV GAŠPARÍK, LUKÁŠ KAPLAN

Department of Wood Processing, Czech University of Life Sciences in Prague, Kamýcká 1176, Praha 6 - Suchdol, 16521 Czech Republic; also Department of Furniture and Wood

Abstract: *Roughness of Thermally Modified Wood at Milling.* This article deals with plane milling of maple wood with consideration of technological parameters, which are of significant effect on arithmetic mean deviation of the roughness profile Ra of the treated wood surface. The measurement of the surface quality was carried out at several different milling parameters. The process of treatment was influenced by the cutting speed, which varied from 20, 30 a 40 m/s and the feeding speed 4, 8 and 11 m/min. The removal at one passing through the material was 1 mm of thickness. Based on the results, it is possible to state that the thermal treatment of wood has no statistically significant effect on the arithmetic mean deviation of the roughness profile Ra. The most significant effect of the observed factors was caused by the feeding speed. The lowest average values of the arithmetic mean deviation of the roughness profile Ra were found at the feeding speed of 4 m/min. The increase of cutting speed has led to decrease of average roughness, whereas the increase of feeding speed led to the opposite effect.

Keywords: arithmetic mean deviation of the roughness profile, feeding speed, treated wood

INTRODUCTION

Since the first attempts of man to treat wood by various means and objects, the process of treatment has passed through an exponential development. Man has gradually learned to use various items and tools for the treatment and such the first treatment machines have originated, powered by man-power (Gaff et.al. 2009). The great improvement of the treatment process has occurred in the context of substitution of physical power of men and animals by mechanical power, which man harnessed from water and wind. At the beginning of the 17th century, the mechanical technology was used for treatment in a very broad scale. The development of treatment, treatment machines and tools continues without interruption till today (Lisičan, 1996). New construction elements and also materials are constantly developed. For the purpose of achieving smooth surface and accurate dimensions of the product, we choose the treatment process of milling. By milling, we mean the treatment by rotating instrument (milling machine, milling head, etc), in which the nominal thickness of the chip varies from zero to the maximum and the feeding is in the direction perpendicular to the axe of the instrument rotation. The choice of the instrument type (milling machine) and its following maintenance is no less important, and therefore it is necessary to pay increased attention to it (Kminiak and Gaff 2014). In the present, not only the machine equipment is being improved, but also the range of treated materials is broadened (Gaff et.al. 2010). One such material is thermally modified wood.

For the purpose of utilization and capitalization of the low-grade raw materials, the method of thermal modification of natural wood has been developed (Gaff and Gáborík 2009). Thermal modification of wood leads to changes of its properties, which we can appreciate especially when used outdoors, for example as a building lining, the construction of building filler etc. (Wang and Cooper 2005). During the production of thermally modified wood no toxic chemicals are used, only heat (and also water vapor or vegetable oils), what is ecologically advantageous from the perspective of production and application of this material (Valenta, 2009). Mainly the most plentifully growing wood species are used for production of thermally modified wood. Of course, other wood species are used for thermal modification too (Reinprecht, 2008). Processes of thermal modification of wood are patent protected. New technologies are constantly searched for, for example.. Royal process, Stellac process and others, with utilization of various thermal media, including other types of vegetable oils and oil resins (Hale et. al., 2005, Spear et. al., 2006).

MATERIALS

As a material, the cut pieces of Acer pseudoplatanus L. from the Poľana region were used. The cut pieces were cut lengthwise to two halves, from which one half was saved for consecutive use and the other half was thermally modified in a device for production of Thermowood (thermal chamber made by Hitwood Oy company, Finland).

Thermal modification was initiated by placing the maple bodies on a metal grill, which was consecutively inserted into the 103/6200 thermal chamber made by Hitwood Oy company, Finland (input parameters are listed in the Table 1). Thermal modification took place in individual time phases. The prepared thermally modified cut pieces were left in relative air humidity of 65% and temperature of 20°C for the purpose of humidity settlement.

Table 1. Thermal chamber parameters

Input technical parameters	
Moisture content of wood	10.5 to 12 %
Filling capacity of TW furnace	7 m^3
Water consumption	885 L
Electricity consumption	2950 kWh
Maximum reached temperature	191 °C

Subsequently, the material was leveled with the STEFF 2034 surfacer (Maggi, Italy) to final thickness of 20 mm. Modified material measured 20 × 100 × 500 mm. Subsequently, the samples were milled by only instrument – by blade at three different cutting speeds (4 $m.min^{-1}$, 8 $m.min^{-1}$ and 11 $m.min^{-1}$) and three different feeding speeds (4 $m.min^{-1}$, 8 $m.min^{-1}$ and 11 $m.min^{-1}$).

Table 2. Technical parameters of the single-spindle bottom milling machine

Equipment	Surface
Manufacturer	Czechoslovak musical instruments
Type	FVS
Year	1975
Supply voltage	380 V
Frequency	50 Hz
Power consumption	5,2 kW
Motor speed	1440; 2880 min^{-1}
Spindle speed	3 000; 4 500; 6 000; 9 000 min^{-1}

Using the Form Talysurf Series Intra 2 contact induction measure instrument made by Taylor Hobson company (Germany), we have measured the roughness of the surface after the plane milling. We have evaluated the measured values using the table evaluation.

RESULTS

By increasing the cutting speed, the value of roughness increased. We have recorded the lowest roughness at cutting speed of 20 $m.s^{-1}$ (Table 3) Gradual change of cutting speed from the lowest to the highest led to increase of the arithmetic mean deviation of the roughness profile Ra. The treated surface showed the worst quality at cutting speed value of 40 $m.s^{-1}$.

Table 3. The correlation of cutting speed with values of Ra

Cutting speed ($m.s^{-1}$)	**20**	**30**	**40**
Cutting speed Ra (µm)	3,56	4,35	4,84
Standard error (mm)	0,12	0,12	0,12
- 95,00 % (mm)	3,25	4,21	4,69
+95,00% (mm)	3,72	4,67	4,95

The increase of feeding speed at milling had a statistically significant effect on values of roughness. By the increase of feeding speed value from the lowest of 4 m.min-1 to the highest of 11 m.min-1, the decrease of the arithmetic mean deviation of the roughness profile of 0,82 µm was recorded (Table 4). However, the difference found between feeding speeds of 4 $m.min^{-1}$ and 8 $m.min^{-1}$ was only 0,3 µm.

Table 4. The correlation of feeding speed with values of Ra

Feed rate ($m.min^{-1}$)	**4**	**8**	**11**
The average value Ra (µm)	2,64	2,34	1,82
Standard error (mm)	0,12	0,12	0,12
- 95,00 % (mm)	2,51	2,21	1,69
+95,00% (mm)	2,98	2,67	2,16

The effect of thermal treatment (Table 5) had no statistically significant effect on the values of the arithmetic mean deviation of the roughness profile. The difference in values of average roughness of the surface between the treated and the untreated wood was negligible. The quality of the thermally modified wood was better in comparison to the native wood.

Table 5 The correlation of the thermal modification with values of Ra

Treatment	**Native**	**160 °C**	**180 °C**	**210 °C**	**240 °C**
The average value Ra (µm)	4,75	4,01	4,15	4,22	4,28
Standard error (mm)	0,12	0,12	0,12	0,12	0,12
- 95,00 % (mm)	4,49	3,89	4,12	4,01	4,75
+95,00% (mm)	4,98	4,25	4,58	4,46	5,02

Based on the listed results, we can conclude that the greatest effect on the arithmetic mean deviation of the roughness profile was the feeding speed.

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Streszczenie: *Chropowatość powierzchni drewna modyfikowanego termicznie przy frezowaniu.* Praca dotyczy frezowania drewna klonu, z uwzględnieniem parametrów obróbki mających znaczący wpływ na jakość powierzchni obrobionego drewna określoną parametrem Ra. Zmiennymi w procesie były prędkość skrawania 20, 30 do 40 m/s oraz prędkość posuwu 4, 8 i 11 m/min. Wysokość warstwy skrawanej to w każdym przypadku 1 mm. Wykazano, że modyfikacje termiczne nie mają statystycznie istotnego wpływu na chropowatość powierzchni wyrażoną parametrem Ra. Największy wpływ miała prędkość posuwu, najlepszą jakość powierzchni zanotowano prze prędkości 4 m/min. Zwiększanie prędkości skrawania prowadzi do polepszenia jakości powierzchni, przy prędkości posuwu zależność jest odwrotna.

Corresponding author:
Monika Kvietková
Czech University of Life Sciences Prague
Faculty of Forestry and Wood Sciences, Kamýcká 1176
165 21 Prague 6 – Suchdol, Czech Republic
email: kvietkova@fld.czu.cz
phone: +420 22438 3750